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ABSTRACT

This study defined a type of information-processing task analysis and an index relating different instructional sequences to this analysis. One hundred sixty-four college students were taught, with computer-assisted instruction, an imaginary science by various instructional sequences or by selecting their own sequence. A program-controlled instructional sequence conforming to the sequence defined by the task analysis was most effective. Learner-controlled sequences yielded poor performance. The contributions of the cognitive abilities of induction, associative memory, and general reasoning to performance under learner and program-controlled sequence and the ability by sequence interactions were shown. (Author)

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Learner and Program-Controlled[1] Sequences of Computer-Assisted Instruction

by

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The relationship of the learning task structure to the instructional sequence was of major importance to this investigation. Several studies have found that following an instructional sequence defined by a Gagné type behavioral task analysis has reduced error rate during learning, but no clear advantage for following a hierarchical learning sequence has been found on a criterion measure following learning. Examples of this class of studies have been Gavurin & Donahue (1961); Miller (1965); Payne, Krathwohl & Gordon (1967); Wodtke, Brown, Sands & Fredericks (1967); and Neidermeyer, Brown & Sultzen (1969). Error rate may be a meaningful index of the effects of disordered sequences since it can reflect, in part, the instructional item transfer interdependency relationships within a task structured by a Gagné type analysis. The studies (Roe, Case & Roe, 1962; Levin & Baker, 1963; Newton & Hickey, 1965; Payne , Krathwohl & Gordon, 1967; and Wodtke, Brown, Sands and Fredericks, 1967) which accumulated error rate data and found no differences in error rate between hierarchical and disordered sequences of instruction also reported no criterion differences in performance. Hamilton (1964) did not report error rate data, but she did not find an effect for instructional sequence.

These findings could be due to task variables, the method of task analysis, methods of presentation (e.g. overcueing), individual differences (e.g. prior task related knowledge and/or ability differences), or the invalidity of the assumption that certain instructional sequences will improve task performance. Some studies have in fact indicated a possible instructional sequence by ability interaction. (Stolurow, 1964 and Levin & Baker, 1963).

Various studies have allowed the learner to determine his own instructional sequence and have demonstrated little or no difference between learner selected sequences and instructional sequences determined by a Gagné type analysis (Campbell, 1964; Campbell & Chapman, 1967; Judd, Bunderson &

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& Bessent, 1970; and Barnes, 1970). A few studies have indicated a positive effect for learner control (Mager, 1961; Mager & McCann, 1961; Dean, 1969; and Grubb, 1969), but in general these have incorporated more learner control than just control over instructional sequence.

This investigation was designed to:

1) determine a method of task analysis which could imply an instructional sequence for optimizing performance on a complex criterion task,

2) define an index which would quantify the proximity of a student's learning sequence to the sequence defined by the task analysis,

3) determine how different degrees of a non-hierarchical program-controlled instructional sequence affects performance,

4) determine the relationship between learner-selected instructional sequences and program-controlled instructional sequences, and

5) determine the relative contributions of several cognitive abilities to different learner and program-controlled instructional sequences.

Structural Analysis

At first the Gagné method appeared to be superior to the other existing methods for determining the task structure, since it was more objective and had received some empirical support. However, when the Gagné analysis was used at The University of Texas, low interjudge reliability of structure determination resulted. The experience gained in trying to perform a task analysis which used the Gagné method led this author to look for a more reliable method than an analysis of the "learning Hierarchy". This low interjudge reliability of structure determination may have occurred since the skills to be learned were restricted to two of the highest levels in the Gagné hierarchy, concepts & principles. Gagné has not suggested any analytic procedures to work within a given level of his hierarchy.

The following method was defined as an attempt to determine the structure of a task which would be objective and would lead to an ordering of steps which would be reproducable reliably.

If one starts with the terminal objective and asks what is the first processing step that should be performed to achieve the terminal objective, then asks what are the succeeding steps one at a time, one can derive a flow of information processing that must occur to reach the terminal objective. This analysis takes a highly specific terminal objective and breaks it down into a set of processing steps which are ordered by inputs and outputs. Process step "x" would be ordered

before process step "y" if the output of step "x" were required as input to step "y".

The task used in this study was considered to be the learning of an algorithm, because rules of computation were learned. The terminal objective for the student was similar to that used by Merrill (1965). To achieve this objective, S needed to use different computational rules in a specific sequence.

An Imaginary Science

The imaginary science called the Science of Xenograde Systems (Merrill, 1965) was chosen for this study. The science can be used in research to bridge basic learning research on one side and curriculum development on the other. The science has the properties of both being somewhat meaningful while having good experimental control.

The newly defined procedure of information-processing analysis was followed to produce a flow diagram of the Xenograde Science. The first attempt produced a less efficient algorithm than the final version. The process used to achieve the final diagram was an iterative one with several revisions before arriving at the end result. There might be a more efficient algorithm than the one used, but this one appeared good. The next step was to program the algorithm in the FORTRAN-IV programming language. To test the rationality of the flow diagram the program was executed by a computer. The resulting output was checked for many different initial conditions and the program consistently produced the correct results. Support thus was provided for the validity of the algorithm. The computer program was not a necessary step in testing the rationality of the diagram, but the computer program did provide an efficient means of generating examples and test items for instructional use.

The next consideration was to break the flow diagram into smaller steps or units which could be taught. The diagram was fragmented so that only one decision had to be made at any given step. This fragmenting procedure involves the instructional analyst in the consideration of step size, which may be unavoidably an empirical question.

A verbal rule was written from each of the steps thus derived. This procedure produced ten rules.

Other methods for determining the structure of a task did not seem to have the characteristic of reproducability of ordering the subtasks once they were defined. The information-processing analysis takes a subject matter expert, but it is thought to be an objective method. If a group of analysts of similar experience with the subject matter were given the terminal objectives, the

subtasks or rules, and the procedure for performing the analysis they should derive essentially the same order. Four people used the procedures and independently derived the same order.

A validation of this analysis was the next consideration, since a satisfactory procedure for the information-processing analysis was attained. To determine if this structural analysis yielded some instructional benefit, it was necessary to quantify the degree of proximity to or departure from this sequence.

Quantification of Instructional Sequences - The HSCI

It seemed reasonable to assume that there were measurably different sequences of presentation which ranged from strict adherence to the task structure to a completely reversed sequence. An index which would specify the degree of conformity of a presentation to the task structure was strongly indicated.

It should be remembered that one result of an information-processing task analysis is a flow diagram which consists of the processing diagrammed as nodes and lines which show the interconnection of the nodes. The lower level nodes are inputs, which implies their being prerequisite, to the higher level nodes into which they are connected. A given subject matter may be composed of a number of these prerequisite units interconnected in various ways.

A unit in the hierarchy could be specified as a terminal node and all of the independent nodes which immediately preceded. It is the assembly of these units upon which the hierarchial sequence conformity index (HSCI) is based. Figure 1 shows the formula for determining the HSCI.

$$HSCI = \frac{\sum_{n=1}^{N} \frac{\sum_{i=1}^{K} Wpn_i}{\text{Number of prerequisite nodes required before a terminal node}}}{N}$$

Where N = the number of prerequisite units in the task,
Wpn_i = the weight of any given prerequisite node,
and K = the number of prerequisite nodes actually attained before a terminal node.

Figure 1: The HSCI formula

The HSCI would have a value of $\bar{W}$ (the mean weight) if all prerequisites in a hierarchy were attained prior to attempting a higher level. $\bar{W}$ would be 1.00 if all weights were 1.00, as they were assumed to be in this study. The HSCI would have a value of 0.00 if no prerequisites in a

hierarchy were attained prior to attempting a higher level. For HSCI = 0.00 it would be necessary for the sequence of instruction to progress in a reverse hierarchial order. This reverse order is the only sequence that would yield a value of zero. Therefore, HSCI ranges from zero to unity. Intermediate values for the HSCI would be attained by various degrees of nonconformity to a hierarchial presentation.

At the present state of knowledge, an assumption of equal weight for all contributing prerequisite nodes within a prerequisite unit must be made. The index gives less weight to any single prerequisite node when the number of prerequisite nodes in a prerequisite unit increases.

There is no way of telling whether or not the task used in this study did violence to the assumption of equal weight without obtaining extensive difficulty statistics for each node and transfer statistics between nodes.

The validity of the index as a meaningful index of systematic variation in sequencing was supported by pilot research. A pilot study demonstrated that the HSCI was linearly related to terminal performance for values of the HSCI from 0.50 to 1.00 under program control.

METHOD

Subjects

Students in five self-paced introductory psychology classes for secondary school teachers at the University of Texas at Austin were required to participate. A total of 176 Ss were initially tested and a total of 164 Ss completed the experiment. Several Ss had to be discarded because of computer malfunctions and several because of illness. Some of the retention test, transfer test, and attitude questionnaire data was lost due to oversight on the part of proctors assisting the experimenter.

Ability Measures

Tests to mark the abilities of interest in this study were selected from the French, Ekstrom & Price (1963) Kit. Associate Memory was marked by the Object-Number Test and by the First and Last Names Test. Induction was marked by the Letter Sets Test and by the Locations Test. General Reasoning was marked by the Ship Destination Test, the Necessary Arithmetic Operations Test, and the Mathematics Aptitude Test.

To obtain the predicted factors from the test battery, it was decided to use a principal axis factor analysis followed by a varimax rotation.

Experimental Task

Merrill (1965) developed a complex imaginary science for learning research called the Science of Xenograde Systems. Merrill's version of the science contains three satellites which revolve about a nucleus containing particles called alphons. The laws and relationships among the various components of the system comprise the subject matter of the science.

A simulation program for the IBM 1500/1800 Instructional System was developed at the Computer-Assisted Instruction Laboratory, The University of Texas. In a series of pilot studies the science was found to be very difficult for Ss to learn. This study used a highly modified version of the science which simplified the content such that learning of the entire science occurred in one hour or less, rather than the four hours needed for earlier versions of the science.

Instructional Equipment

Instruction was administered by the IBM 1500/1800 Instructional System. Presentation of materials was by means of a cathode ray tube display, a computer-controlled image projector, and by mimeographed handouts. Student responses were entered by means of a keyboard at the computer terminal. Other responses were recorded on mimeographed forms with pencil.

Design

A pilot study using a design similar to the present one with 49 students from introductory psychology courses indicated that the HSCI might be a valid index related to performance and that the other questions were worth pursuing. Support for the validity of the HSCI in the pilot study came from a linear trend for the HSCI to be positively related to performance over the range (0.50 - 1.00) of the HSCI values sampled when sequence was under program control.

In the current study one group called the self-selected (SS) group was used which allowed S to choose his own sequence of rules. The S was also allowed to repeat individual rules; although with each repetition the example was different. Two related representations of the structure of the imaginary science were provided S. A flow diagram of the task and a list of the behavioral objectives of each of the ten "lessons" (rules) served as the two representations. For comparison another group was yoked S for S to group SS. This yoked (Y) group was not provided with the representations of the task. A member of group Y was given the sequence determined by the subject to which he was randomly matched. He received the same number of examples on each rule in the same order as his randomly paired S in group SS had chosen. It was expected that uneven distributions of Ss classified by HSCI would result for group SS and thus for group Y. Although the availability of

a task representation was not thought to be a major variable affecting performance in group Y, two other groups were included to confirm this assumption. These two forced sequence (F) groups were included to determine the effect of the representations on performance when the sequence of instruction was previously determined and no repetitions of any rule were allowed. Equal distributions of Ss classified by HSCI were established for the two F groups. If no difference was detected between the two F groups then the effect of the representation could be considered nil and the two F groups at each level of the HSCI for a predetermined sequence could be combined. The combined F group with group Y then would be compared to group SS to determine the relative effects of self-selection and program control of sequence.

The posttest designed to test the terminal objective was given on the computer. The terminal objective is: given the initial conditions of ACN, ACS, Distance, and Force Field (F F), the student will be able to produce a complete table of Xenograde readings line by line from time zero up to any specified time. Each successive line in a Xenograde table requires information from the preceding line. Because of this, correct scoring required a preceding line to be correct or the following line would also be in error. Thus, student errors were scored by the computer program and corrected immediately. This in effect resulted in a correction procedure which could introduce learning into the posttest measurement situation. A control (C) group was necessary to assess the effect of the correction procedure. One group was assigned the task of taking the posttest without any instruction, except how to operate the computer terminal. It was assumed that learning in group C would be due to the corrective feedback following errors. The mean score for this group was used as a base level of performance on the posttest.

Table 1 is a summary of the experimental design showing the differences and similarities of treatment among the groups during the learning phase.

Table 1
Summary of the Experimental Design

Group	Number of times a rule could be taken	Structural Representation Available	Predetermined Sequence?
Self-selected (SS)	n*	yes	no
Yoked (Y)	n*	no	yes
Forced without representation ($F\bar{R}$)	1	no	yes
Forced with representation (FR)	1	yes	yes
Control (C)	0	no	--

* Subjects in group SS may repeat any given rule n times, where $1 \leq n \leq 5$. The subject randomly matched to a S in group SS received the corresponding rule the same number of times.

Dependent Measures

Various indices of performance were taken. These included a posttest, retention test taken two weeks after the posttest, a transfer test taken after the retention test, and an attitude questionnaire.

Time to learn the science. The length of time from presentation of the first rule until the student completed the instruction was accumulated to indicate the total time spent by the student in the task.

Posttest - retention test. The test of the terminal objective (posttest or retention test) contained either 132 or 144 items. Since the test had to be given twice to each S, two forms were desired. No statistics were available as to whether the tests were parallel or not; therefore half of each group received one form and one-half the other form for the posttest. To measure retention S completed the form which he had not previously taken. The tests were constructed so that the same behavior was measured with comparative frequency by both forms.

The test required S to fill in each entry in a table, line by line by keying entries which appeared in context in the table on a cathode ray tube. After completing a line S was informed of his incorrect responses, and the correct answer replaced any incorrect ones. No specific feedback action was taken if S's answer was correct. As soon as S completed the test he was told how many items he had answered correctly. This total score was converted to percent correct and used for the primary analysis as a measure of overall proficiency for the posttest and as the only criterion for retention. The conversion to percent correct allowed the two alternate forms of the test to be compared since there was a small difference in the total number of items between the two forms.

Transfer test. The transfer test required S to infer three new rules of the science given two example tables. The subject then completed nine test items of the same format as was used for test questions during the science instruction. Fifteen minutes were allowed for this task, and the total number correct was used as the dependent measure.

Attitude questionnaire. The attitude questionnaire was a checklist consisting of ten items. Ten statements related to the task were given and S had to mark a four choice scale ranging from "strongly agree" to "strongly disagree".

Procedure

During five two-hour sessions large groups of Ss received a thirty minute lecture presentation by E. The lecture covered an introduction to CAI, ability by treatment interaction studies, and the value of their participation in this study. These presentations were given in order to develop Ss interest in the study. Each S elected which one of the five sessions he wanted to attend

Immediately following the lecture, Ss were tested on selected cognitive abilities. Seven tests from the battery (French et al., 1963) were used to mark the factors of Associative Memory, Induction, and General Reasoning.

Following the testing Ss were told to make individual appointments at the Computer-Assisted Instruction Laboratory. Each S scheduled two appointments with a two week interval between appointments.

At the first session in the lab, S was first given an introductory course administered by the computer which taught terminal operating conventions and procedures. It was hoped that the introductory course helped to desensitize S to the terminal and CAI before instruction began.

After S had completed the introductory course, he was given a booklet to read. This booklet gave an introduction to the Xenograde science, the justification for learning the science, some humorous background material, instruction for reading the computer terminal data displays, and group specific procedures. As soon as S finished reading the booklet, he took the CAI program to learn the science.

If S were in groups Y or F he was assigned a sequence of instruction by a proctor at the beginning of the computer-administered course. The science was composed of ten "lessons" each of which consisted of one rule, an example, and three test items. Simultaneously presented with each rule was a unique example. When S believed that he understood the rule, he indicated that he was ready for a test of the rule by typing the word "test" at the terminal keyboard. The subject was then required to type a numeral to fill in a missing piece of data on a display. The item required the use of the rule to obtain the correct answer. Following three such test items, S was informed of how many items he had answered correctly; although he was not given the correct answers. The next rule was then presented and S went through the same procedure. The subjects in one of the F groups (FR) were given the two representations, a flow diagram of the task structure and a list of behavioral objectives, and told to study them carefully before each rule-example presentation. As soon as the last rule was completed S was told that he had completed the task and was ready for

the posttest. The first lab session was completed as soon as S completed the computer-administered posttest.

Two weeks after the first lab session S returned and took the alternate form of the computer-administered test (retention test). After completing the retention test S was given the mimeographed transfer test. A mimeographed attitude questionnaire was then given to each S.

At the beginning of the learning session Ss in group SS were shown a diagram of the hierarchy. The behavioral objectives in their booklet corresponded to this diagram. After studying both representations S selected the lesson that he wanted to take by typing in a letter corresponding to the desired lesson at the keyboard. The rule and corresponding example were then presented. Following observation of this rule and example, S typed the word "test" and then completed the three test items. After having been informed how many items he answered correctly S was returned to the diagram of the hierarchy to select the next lesson. If S selected the same rule again, he was given the same rule but a new example and different test items. His selection of the sequence of instruction continued until he indicated that he had taken at least one example of each rule and had done enough work to take the criterion test. The remaining tests and attitude questionnaire for group SS were the same as for the other groups.

While taking the course, Ss were not allowed to have any paper or pencils with them. Subjects were also asked to refrain from discussing the particulars of the course with others who were yet to take the course.

RESULTS

Because of the complexity of the research design there was no simple test of each hypothesis. A difference between groups may in some cases have been due to several confounding factors. Each of the different dimensions along which groups varied (see Table 1) needed to be tested to eliminate alternate explanations of any obtained group differences.

The primary performance criterion of interest was the total per cent correct on the posttest.

Test of Variations in the Information-Processing Defined Sequence

The first two-way classification (2 x 5) analysis of variance was computed with groups FR and $\overline{FR}$ as one factor and five levels of the HSCI as the other factor. No significant differences were found for the groups or groups x HSCI interaction. The HSCI factor yielded significant

effects for total percent correct on the posttest ($F(4/42) = 2.60$, $p < .05$). No effect for the HSCI was found for the time to learn criterion. The findings indicate that for a predetermined sequence the hypothesis of no effect of task representation (presence or absence of behavioral objectives and a flow diagram) on performance could not be rejected.

The second two-way classification (2 x 5) analysis of variance was computed with groups F (FR and $\overline{FR}$ combined) and Y as one factor and the five levels of the HSCI as the other factor. No groups x HSCI interaction was found, but there was a significant difference between the F and Y groups in total time to learn the science ($F(1/74) = 8.97$, $p < .005$). The difference is not surprising since Ss in group F took only ten examples and Ss in group Y took between ten and nineteen examples with a mean of 11.4. The mean number of examples for group Y was significantly larger than the number of examples for group F ($t = 4.85$, $df = 51$, $p < .001$ two-tail). Number of examples seemed to lengthen the amount of time to learn the science without significantly increasing criterion performance. The HSCI factor again yielded significant effects for the total per cent correct on the posttest ($F(4/94) = 4.25$, $p < .005$), but no significant effects were detected for time to learn.

The significant differences found which were attributable to the level of the HSCI justified further inspection of the data. A non-hierarchical sequence, as defined by the HSCI, would be any sequence having HSCI $\neq 1.00$.

The first set of comparisons used HSCI = 1.00 vs. HSCI $\neq$ 1.00. The combined preselected sequence groups (FR, $\overline{FR}$, and Y) showed no significant mean differences. When each of the groups (FR, $\overline{FR}$, and Y) were analyzed separately only one produced significant differences. The scores for group $\overline{FR}$ were divided into two groups according to whether they received a hierarchical instructional sequence (HSCI = 1.00) or not (HSCI $\neq$ 1.00). An unequal ns test showed a significant difference for the total percent correct on the posttest ($t = 3.30$, $df = 24$, $p < .01$ two-tail). No differences were found between the groups when time to learn was used as the criterion. The differences indicated higher mean performance when the HSCI was 1.00.

Tests for the difference between the means at HSCI = 1.00 and the means at the other values of the HSCI were calculated.

Only the comparisons between groups for the HSCI = 1.00 and HSCI = 0.25 yielded significant results. The total per cent correct on the posttest ($t = 2.72$, $df = 47$, $p < .01$) was significant. The total attitude score did not reflect this significant difference, nor were differences in

time to learn detected.

An apparent reversal in the trend for performance to decrease as HSCI approached zero at HSCI = 0.00 for a predetermined sequence was replicated by three independent groups (FR, $\overline{FR}$, and Y) and also in the pilot data for this experiment. Although testing for differences in mean performance between the HSCI = 0.00 and HSCI = 0.25 produced no significant values, the multiple replication of this ordering of the mean values suggests a stable phenomena.

Learner and Program Controlled Sequences

The lowest performance of all the groups which studied the science was for group SS, and group C appeared to have a relatively high level of performance. A test of the mean differences between these groups yielded a highly significant result ($t = 3.61$, $df = 58$, $p < .001$) for the posttest total percent correct.

Obviously a large percentage of the answers on the posttest can be "guessed" after observing the trends produced by the feedback procedure, but there still remains a highly significant number of items which are difficult to answer correctly without instruction.

It would have been desirable to have used analysis of variance techniques, as in testing the first two hypotheses; but group SS failed to meet sampling assumptions on the HSCI factor. By interacting with the materials each S determined his sequence rather than being randomly assigned a sequence and corresponding value of the HSCI. The only index of the linear relationship of the HSCI to performance for group SS was the lack of correlation of the HSCI to the total per cent correct for the posttest ($r = 0.03$).

Disregarding classification on the HSCI, two-tail t tests were computed for the mean differences between groups Y and SS. Contrary to previous studies group Y was found to have superior performance. The total per cent correct on the posttest approached but did not quite reach a level of significance ($t = 1.87$, $df = 102$, $p < .10$). No differences were detected between groups Y and SS on the retention test, or transfer test.

The other prediction was for a difference in the attitude toward the task. No difference in total attitude scale score was found. Of all the items on the attitude scale only one item discriminated the groups ($t = 2.06$, $df = 93$, $p < .05$), but the result was in the opposite direction to that predicted. A more positive attitude was indicated by group Y.

The difference which was detected between group Y and SS would seem to be attributable to the difference between self-selecting a sequence and being forced through a sequence. Table 1

showed that the SS and Y groups also differed in respect to the presence of a diagramatic representation of the science which was the only difference between groups FR and $F\bar{R}$. It seems reasonable to infer the difference between groups SS and Y was not due to the presence of the task representation.

Cognitive Ability and Instructional Sequence

This portion of the study required the application of several analytical procedures. First a factor analysis of the ability test battery was computed for purposes of ability construct validation.

Factor analysis of the ability tests. The major abilities of interest in this study were Induction and Associative Memory. The four tests used to mark these abilities as well as the three tests used to mark the General Reasoning ability were subjected to a principal components analysis. These factor loadings were then rotated by a varimax procedure. A clear factor structure yielded three factors interpreted as being General Reasoning, Associative Memory, and Induction. Factor scores for each individual were obtained and used in the subsequent analysis of the role of abilities.

Contribution of abilities. Linear regression models (Bottenberg & Ward, 1963) were used to test questions concerning the contributions of abilities to performance and the interaction of abilities with the HSCI. The analysis was performed on pooled data from all Ss having a preselected sequence of instruction. No differences were found among these groups on any criterion (except difference in time to learn the science between groups F and Y); therefore, it seemed justifiable to pool them for this analysis.

For testing the hypothesis of ability by sequence (HSCI) interaction each ability measure was used separately, and tests were made to see if the regression lines of ability on the total percent correct on the posttest were parallel among the levels of the HSCI.

The measure for Associative Memory yielded a full model which predicted better than just the mean score ($F(10/88) = 2.976$, $p < .005$). The resulting R^2 was 0.25.

Imposing the restriction of parallel slopes for Memory scores among HSCI levels on the criterion produced a nonsignificant difference from the full model ($F(4/88) < 1.0$).

The other ability by instructional sequence test was made using the Induction measure. The full model predicted the criterion score significantly better than just the mean score ($F(10/88) = 4.070$, $p < .0005$). The R^2 for the full model was 0.32.

Imposing the restriction of parallel slopes for Induction scores among HSCI levels on the criterion produced a significant difference from the full model ($F(4/88) = 2.90$, $p < .05$). The Induction ability was the only ability measure found to interact with the predetermined sequence of instruction as defined by the HSCI. In general Ss having low induction scores were more affected by progressively disordered sequences than were Ss having high induction scores.

The question of the "main" effect of an ability was not a meaningful question for the case of Induction.

The criterion scores for the preselected sequence group were split into two groups defined as being above or below the median Memory score for the total group. A two-tail t test indicated a difference ($t = 2.39$, $df = 96$, $p < .02$) between these groups. Consistently higher performance for the higher Memory scores across the HSCI.

For the learner selected sequence a significant positive relationship ($r = 0.41$, $p < .01$) between total per cent correct on the posttest and General Reasoning scores was found. A positive but smaller correlation ($r = .22$) was found for Ss having a preselected sequence.

DISCUSSION

The information-processing analysis proved to be a reliable and an objective method in the sense that a number of persons independently arrived at the same sequence of steps once the elements of the task structure were defined. The question of the validity of this analysis was not as clearly answered. It was predicted that if this information-processing analysis defined a sequence of instruction which improved learning performance, then as an index of conformity to hierarchical sequence (HSCI) decreased from 1.00 to 0.00 performance would correspondingly decrease. This test of the validity of the analysis assumed that the HSCI gives an ordinal measure of the degree of conformity to this analysis. Any departure from the predicted result could be due to an invalid analysis, an invalid HSCI, both the analysis and the HSCI invalid, or an invalid assumption that hierarchical sequences facilitate learning.

This study did not support Neidermeyer's (1968) conclusion that instructional sequence for relatively short programs is of minimal importance.

In general, a covariation between the HSCI and performance was found for preselected sequences. This positive contribution for a hierarchical instructional sequence held over time

and through the transfer test as well as yielding a more positive attitude for some Ss. The only seeming inconsistency of this relationship was the performance change at HSCI = 0.00. Although not found to be a statistically significant change, the same effect was independently observed in all predetermined sequence groups and in a pilot study. If this inconsistency were a real effect, then several possible explanations could be given. The HSCI may not accurately define the degree of conformity of the instructional sequence to the task analysis. There was, however; the predicted relationship over a major portion of the range of the HSCI (0.25-1.00). The HSCI has a value of 0.00 only when the instructional sequence is completely reversed from that of the information-processing analysis structure. This point where HSCI = 0.00 is easy to define independently of the HSCI as it is to define a sequence which progresses in an ordinal fashion through the structure. The only descriptive utility of the HSCI is for the interim range of disordinal sequences.

There may have been a peculiarity of the terminal objective or of the entire task which had a facilitative effect for a completely reversed sequence. This alternative explanation could only be answered by a similar experimental design using another task.

It seems unlikely that the information-processing analysis is completely invalid, since performance tended to covary with the index of proximity to the defined structure, the HSCI.

A self-selected sequence of instruction did not produce a high level of performance as some studies had indicated it might. The lack of correlation between the HSCI and performance for a self-selected sequence indicates the lack of a systematic effect of sequence on performance when S chooses his own sequence. It was found that self-selection of sequence led to lower performance than a hierarchical predetermined sequence. The implication of this finding is that a task analysis is a worthwhile endeavour; since it can lead to the definition of a hierarchical presentation sequence which increases performance, at least for some learner populations.

It would be difficult to explain the low scores for group SS by stating that the representation had no meaning for them; thus they had nothing to assist them in selecting their sequence. Group Y was given no representation, and the randomly matched S in group Y received the same steps in the same sequence as the S from group SS to which he had been paired. The performance of group Y was significantly higher than that of group SS. It would seem that having the freedom to select one's own sequence and repeat steps which were unclear would be more meaningful and aid learning more than being shown steps in a sequence which bore no relationship to one's previous performance, but the data do not bear this out.

The task used in this study differed in several possible ways from the tasks used in the studies finding a benefit for learner-generated sequences. This task used in this study was completely new to all Ss. In some of the previous studies (Mager, 1961; Mager & McCann, 1961) the Ss were familiar with some of the large units in the task. In the study by Campbell and Chapman (1967) the learner-generated sequences were of only large units of a possibly non-hierarchical task. The smaller steps were given as units of presequenced materials, and even then group discussions followed the individual learning sessions. This study was also conducted over a shorter time span than the studies finding a positive contribution for self-selected sequences. Learners may need experience and training to make self-selection of sequence beneficial

Self-selection of sequence may be found to be a beneficial technique when used for selecting and sequencing missing units as in review, or when the task is not hierarchical, or when the steps to be sequenced are large steps composed of smaller presequenced materials, or when used over a longer time span, or any combination of the above. The technique of learner-generated sequence was unsuccessful when the task was a relatively short, abstract, mathematical-scientific system taught as small steps and of which the students had no prior experience.

To obtain enough Ss for a meaningful analysis of the abilities the groups having a predetermined sequence were combined. No difference on any dependent measure, except the time spent studying the science materials, was found among these three groups; so the decision to combine them seemed reasonable. The statistically significant ordinal interaction between the sequence of instruction, as defined by the HSCI, and the Induction scores had the generally expected shape. It was expected that an individual who had a high measure on the Induction ability would be less affected by a disordinal sequence than would an individual having a low measure on this ability. Perhaps this ability facilitated the inducing of ordering of steps in the composite task which were not presented in an ordered manner. As the sequence of instruction became more ordinal, a larger number of the prerequisite steps were taken before the higher level steps thus reducing a reliance on an Induction ability.

The Memory ability measure was not found to interact with the HSCI, but a higher level seemed to increase performance scores relatively equally for any value of the HSCI. As Ss Memory ability increased his performance increased. This ability might have helped S remember the verbal rules which were taught, rather than the order of rules per se. As Pavne & Krathwohl (1967) suggested, Memory and Induction made a positive contribution to performance.

As was expected there was a strong positive relationship between performance for group SS and the Reasoning ability. It was expected that this measure would aid in organizing and structuring the task to facilitate performance. Induction was also highly related to performance for this group. It could be that by not following the hierarchical structure this ability was called upon in a similar manner to that described for the preselected sequence group. It could also have been that due to a lower level of learning, Induction was important in inducing the necessary behaviors from the posttest feedback procedures. The Memory ability seemed to be unrelated to performance for group SS.

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